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European summer climate variability in a changing climate

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Climate projections suggest that the European summer climate might undergo considerable increases in variability on a wide range of time scales, from synoptic (intraseasonal) to seasonal to interannual. Such changes would have a profound impact upon the frequency and character of extremes, notably the frequency and character of summer heat waves. In particular, it could explain major heat waves far off the mean. Here we present a review of recent studies on European summer climate variability, an analysis of climate model simulations, and an assessment of underlying processes. While greenhouse gas forcing has been shown to lead to changes in variability in many models, there are considerable differences between individual simulations. An intercomparison will be presented between the PRUDENCE and ENSEMBLES set of regional climate model (RCM) simulations. Most model simulations yield an increase in synoptic and seasonal temperature variability, and the majority but not all models also exhibit an increase in interannual temperature variability. In general, interannual variability changes are more pronounced in the PRUDENCE set of experiments. This difference is not fully explained by the use of different scenarios (SRES A2 in PRUDENCE and A1B in ENSEMBLES). We will discuss these differences and address how the RCMs and driving GCMs influence this spread in results, and how changes in large-scale circulation patterns may affect variability changes. Uncertainties are also related to the representation of parameterized physical processes (in particular land-surface processes, convection and cloud-radiation interactions). The processes driving variability increases on seasonal to interannual time scale are related to soil moisture memory and associated with a pronounced progression of the warming / drying during the summer season. In particular, most models project a warming that is considerably stronger during late August than early June, thus yielding an increase in seasonal variability. Also the projected intraseasonal variability increases are amplified by dry soils, but without necessarily relying on the aforementioned memory effect: As the drying reduces the evaporative fraction, the same intraseasonal variations in net radiation may in principle translate into larger intraseasonal temperature variations over dryer soils. In addition, several models exhibit increases in the variability of surface net radiation. Other factors that may contribute are changes in mean cloudiness. The relative contribution of these processes differs substantially between models. An important feedback that interferes with changes in variability is the soil-moisture precipitation feedback. A positive feedback would tend to amplify hydrological and temperature variations, while a negative feedback would have a moderating effect. Recent studies show that there is considerable uncertainty about this feedback (and even its sign under current climatic conditions). It is an important challenge to address these uncertainties. Note in particular that model biases in the representation of current interannual variations may raise doubts about the projection of future decadal variations.